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RECLAMATION OF INDIAN AND ABRAMS CREEKS IN GREAT SMOKY MOUNTAINS NATIONAL PARK

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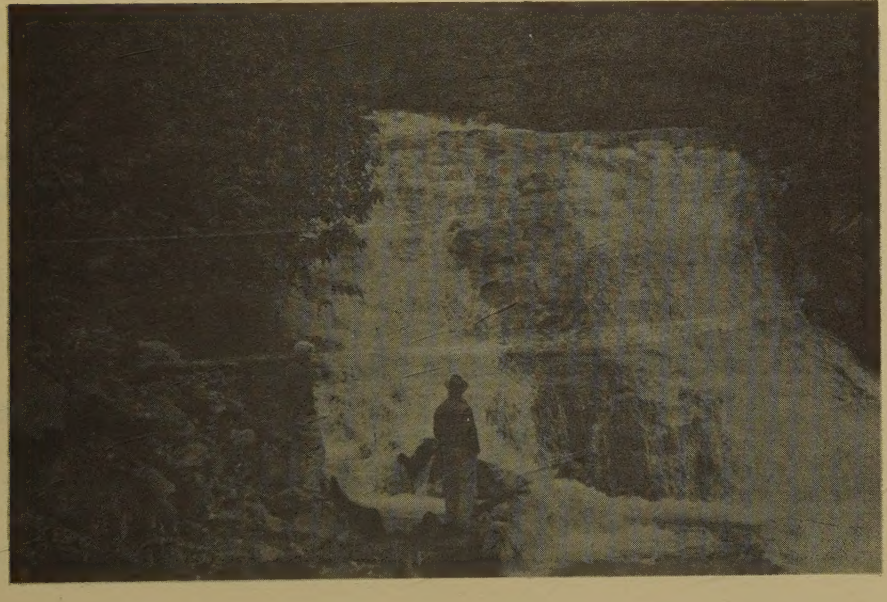
THE RECLAMATION OF INDIAN AND ABRAMS CREEKS GREAT SMOKY MOUNTAINS NATIONAL PARK

By
Robert E. Lennon and Phillip S. Parker
Fishery Research Biologists
Appalachian Sport Fishery Investigations
Leetown (P.O. Kearneysville), W.Va.



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ABSTRACT

A complete program of stream reclamation was developed and applied on Indian and Abrams creeks in Great Smoky Mountains National Park. A salt-resistivity technique was used to estimate the dilution and velocity of a toxicant in running water. Streamside toxicity trials on resident fishes established minimal, effective concentrations of the rotenone material. The successful removals of undesirable fish were followed by restocking with selected strains of eastern brook trout and rainbow trout. Post-reclamation observations demonstrated enhanced survival, growth, reproduction, and catch of trout. Factors which might limit the effectiveness of stream reclamation programs are discussed.

THE RECLAMATION OF INDIAN AND ABRAMS CREEKS GREAT SMOKY MOUNTAINS NATIONAL PARK

The restoration of productive sport fisheries in lakes and ponds through the chemical control of undesirable fishes is an accepted and valuable practice in fishery management. The development of equipment and techniques has progressed to the point where a wide variety of standing waters can be effectively reclaimed. The many successes which have been achieved in warm water and cold water lakes have prompted fishery biologists to consider the reclamation of streams with toxicants.

There is no doubt that sport fisheries could be established or improved in a large number of streams if rough and competitive fishes were controlled or eliminated. Populations of rainbow trout were improved in streams of the Russian River drainage in California by the reduction of rough fish with rotenone (Pintler and Johnson, 1958). The natural and man-made barriers which exist on many potentially productive streams would inhibit the future ingress of undesirable fish and would thereby enhance the reclamation opportunities. The benefits to sport fishing from the reclamation of streams can be very great once the techniques for treating a wide variety of running waters are developed.

There are important problems involved in the reclamation of running water. A lethal concentration of toxicant must be maintained over miles of stream despite factors of stretch-out and dilution. The fish at any given point in a stream must be exposed to the toxicant for an effective length of time in order to obtain a kill. These problems are complicated by the variable rates of stream discharge and velocity, by the temperature of the water, and by the greatly divergent susceptibilities of various species of fish to a toxicant at a given concentration and period of exposure. Consequently, the dimensions of a bolt of toxicant moving down a stream have to be carefully prescribed.

An investigation was made in Great Smoky Mountains National Park in 1957 and 1958 on the factors and their interrelationships which influence both the concentration of a fish toxicant and the duration of exposure in streams. The reclamation of Indian Creek was undertaken in May 1957 to determine the mechanics of treating a soft water, mountain stream with rotenone and to test the possibility of re-establishing a population of eastern brook trout. A short time later 46 species of game, rough, and exotic fishes were eliminated from a 14.6-mile section of Abrams Creek in an effort to establish a rainbow trout fishery.

Indian and Abrams creeks are two of the many trout streams in the park, all of which drain into the Tennessee River system. Fair to excellent populations of wild rainbow trout occur in most of the streams and they sustain most of the fishing pressure. The native, eastern brook trout was once abundant but it is now restricted to the headwaters of certain streams. Brown trout, smallmouth bass, and largemouth bass exist in relatively small numbers in the lower courses of some streams. To date, 71 species of fish have been identified in the park but the distribution of many of them is restricted by the numerous barrier falls. Some of these species are undesirable exotics which have migrated in from new impoundments on the Little Tennessee River. In time it may be desirable to control the populations of certain exotic species to preserve or improve the sport fisheries.

PRELIMINARY TRIALS

A liquid preparation of rotenone, marketed as Pro-noxfish, was the toxicant selected for the reclamation of Indian and Abrams creeks. Composition by weight was 2.5 percent rotenone, 5.0 percent other cube extractives, and 2.5 percent sulfoxide. The sulfoxide has a synergistic effect on rotenone and this formula is designed to be as

effective on fish as preparations which contain 5 percent rotenone. Hester (1958) found however, that Pro-noxfish was somewhat less effective on 7 species of fish than Noxfish which has 5 percent rotenone.

The principal problem pertaining to the application of rotenone in a stream involved a determination of the quantity of toxicant needed to provide an uninterrupted and adequate concentration for an effective period of time. The fact that a chemical agent stretches out and becomes greatly diluted over a relatively short distance in running water was observed during many collections of fish in the park with cresol anesthetic. It appeared that quantitative estimates of the concentration of toxicant, the duration of exposure, and the factor of dilution could be obtained with a dye and comparator tubes or with stock salt and a resistivity meter. Both methods were tried but the latter one proved the better since some observations had to be made over long distances at night in turbid water and in stormy weather (Lennon, 1959).

The salt-resistivity technique was extensively employed in prereclamation surveys on Indian and Abrams Creeks. For example, salt was added to Indian Creek on one occasion at an average rate of 12.2 ppm for a 15-minute period. The bolt of salt water reached a point 3.5 miles downstream in 2 hours and 34 minutes. It had become stretched out and required more than 2 hours to pass the check point. It had become diluted from 12.2 to 2 ppm. On the basis of similar trials at different rates of stream discharge, the stretch-out, dilution, and velocity of a bolt of rotenone emulsion moving downstream were estimated. Strengthening stations were located downstream so that additional rotenone could be superimposed on the residual toxicant in the stream to maintain a killing concentration for the required period of time. The data on velocity also contributed to the timely deployment of crews to man the strengthening stations and to collect fish.

The particular problems in respect to the fish in Indian and Abrams Creeks were these: what species were present, and what concentrations of rotenone and lengths of exposure were required to kill the more resistant of them? Samples of the fishes in both streams were obtained with electrofishing gear and cresol. The extensive collections made in Indian Creek showed that rainbow trout, eastern brook trout, and longnose dace were the only species present in the section of stream to be reclaimed. Partial collections and reports of anglers on lower Abrams Creek indicated that there were at least 30 species of fish present. They included lampreys, gizzard shad, trout, suckers, carp, dace, shiners, stonerollers, catfishes, killifish, sauger, darters, rock bass, smallmouth bass, sunfish, drum, and sculpin.

Specimens from the collections were used in streamside toxicity trials with Pro-noxfish. The trials were conducted in hatchery troughs set up on Indian Creek and on Abrams Creek to avoid the possible complications due to different waters or different water temperatures. Water for the troughs was taken directly from the streams. The test fish were held in livecars in the streams until used.

On Indian Creek, all rainbow trout (3.9 to 13.2 inches long) and longnose dace (3 to 5 inches long) tested were killed when exposed to 0.5 ppm or more of the toxicant for 1 hour at water temperatures of 56 to 59° F. Several trout (4 to 5 inches long) survived up to 105 minutes in a 0.1-ppm concentration at 58°. On the basis of the trials, it was decided that a minimum concentration of 1 ppm of toxicant would be maintained for 1 hour throughout Indian Creek to eradicate the trout and longnose dace.

On Abrams Creek, a total of 230 fish (0.5 to 23.2 inches long) of at least 14 species was used in toxicity tests. The concentrations of the toxicant tested ranged from 0.1 to 3.25 ppm, and the water temperatures ranged from 64° to 72° F. (table 1). Carp were more difficult to kill than other species. Three specimens, 14.4 to 18.5 inches long, died only after a continuous exposure of 5 to 6 hours in a concentration of 0.1 ppm of the toxicant at 64°. Another carp, 18.6 inches long, turned over after 30 minutes in a 1-ppm concentration at 67° and appeared to be dead after 3 hours of exposure. It recovered fully however, after it was removed from the test trough and placed in a livecar in the stream.

Stonerollers were relatively resistant to the toxicant and survived up to 3 hours and 55

Table 1:- The results of toxicity trials in which fish were exposed to several concentrations of rotenone in troughs at Abrams Creek Campground on June 6 and 7, 1957. Both the water and the fish used in the troughs were taken from Abrams Creek.

Species	Number of fish	Size range (inches)	Concentration of rotenone (ppm)	Average and range of time to Turnover (minutes)	Average and range of time to Death (minutes)	Water temperature (°F.)
Carp	3	14.4-18.5	0.10	69 (60-80)	338 (300-360)	64
"	1	18.6	1.00	30	... 1/	67
"	2	18.6-23.2	3.25	32 (11-52)	205 (170-240)	64
	6					
Hog sucker	2	2.6- 8.5	0.50	30 (19-40)	56 2/	64-68
" "	3	10.5-13.1	1.00	24 (21-26)	66 (61-70)	64-67
" "	1	8.0	3.25	10	37	65
	6					
Golden redhorse sucker	1	14.0	0.50	23	87	64
" " "	1	12.0	1.00	19	63	67
	2					
Stoneroller	11	3.5 - 7.1	0.50	28 (15-50)	148 (110-235)	64
"	9	3.3 - 6.4	1.00	22 (18-29)	68 (36-109)	67-70
"	29	2.3 - 6.1	2.00	9 (3-16)	38 (26-54)	71-72
"	8	2.5 - 6.2	3.25	7 (5-13)	28 (18-38)	65
	57					
Bigeye chub	3	2.4 - 2.9	2.00	4 (2- 7)	17 (15-19)	71
Chubs (Hybopsis spp.)	4	4.7 - 5.4	0.50	19 (12-25)	87 (73-96)	64
"	6	2.3 - 6.0	1.00	15 (12-23)	60 (41-71)	64-67
"	3	2.5 - 5.9	2.00	8 (3-17)	31 (20-51)	69-71
	13					
Warpaint shiner	8	2.7 - 4.9	0.50	12 (5-25)	42 (35-55)	67-68
" "	12	3.1 - 4.8	1.00	12 (4-18)	53 (25-76)	64-68
" "	1	3.4	2.00	6	17	71
" "	6	3.1 - 5.8	3.25	8 (4-11)	19 (13-31)	64
	27					
Whitetailed shiner	1	5.6	2.00	12	26	69
Spotfinned shiner	2	2.8 - 2.9	2.00	11 (10-11)	23 (22-23)	71
Madtom	1	2.3	0.10	17	78	64
Logperch	2	4.8 - 5.3	0.10	20 (15-24)	65 (64-65)	64
Darters (Etheostoma spp.)	4	1.9 - 3.9	0.10	24 (19-28)	62 (51-82)	64
"	3	2.1 - 2.7	0.50	9 (8- 9)	48 (40-54)	68
"	1	2.4	1.00	15	42	67
	8					
Smallmouth bass	2	7.1 - 7.1	0.50	20 (14-25)	95 (66-123)	67
" "	2	7.0 - 8.4	1.00	18 (17-18)	34 (33-35)	67
" "	3	5.0 - 8.0	2.00	13 (12-16)	33 (28-38)	69
	7					
Rock bass	2	3.8 -10.2	0.10	56 (28-83)	142 (101-183)	69
" "	9	2.1 - 9.2	0.50	68 (11-139	110 (33-169)	64-68
" "	3	3.7 - 5.8	1.00	13 (10-18)	28 (25-31)	68
" "	8	4.9 - 9.7	2.00	13 (10-17)	32 (28-46)	69
	22					
Fry, several species	23	0.5 - 1.5	0.10	46	.. (58-90)	64
including redhorse suckers,	35	0.5 - 1.5	0.10	73	173	67
stonerollers, shiners, and	15	0.5 - 1.5	0.50	7	35	64
smallmouth bass.	73					
Grand total	230					

1/ Survived 3-hour exposure

2/ One specimen survived 3.25-hour exposure

minutes in a concentration of 0.5 ppm and up to 1 hour and 49 minutes in 1 ppm. One hogsucker survived an exposure of 3 hours and 15 minutes in a 0.5 ppm concentration and recovered fully when it was returned to a livecar.

None of the fish except shiners and darters had an average time of death of less than 1 hour when exposed to 0.5 ppm of toxicant. Smallmouth bass and rock bass were killed in 1 hour or less when concentrations were 1 or more ppm.

The wide range of responses exhibited among the small numbers of specimens of each species indicated that both the minimal effective concentrations of toxicant and the durations of exposure necessary in a stream might be greater than the tests showed. It was decided that a concentration of at least 1 ppm would be adequate in Abrams Creek if it were maintained for a minimum of 6 hours in an uninterrupted bolt. On the basis of the salt-resistivity tests on Abrams, it appeared that the desired bolt of toxicant could be established best by applying the Pro-noxfish at a rate of 5 ppm for the first hour and at the rate of 1 ppm for 5 hours thereafter.

The wide range of results in the toxicity trials also indicated the need for additional tests with larger numbers and more species of fish. There was no opportunity to do so prior to the reclamation of Abrams, but it was apparent that such data would be of value in planning the reclamation of other streams. Tests were made, therefore, with 461 fish of 24 species in 2 trout-rearing pools on Anthony Creek, a major tributary of Abrams Creek. The results are included here since they are pertinent to the problems of stream reclamation (table 2).

The concrete rearing pools are 50 feet long and have individual sources of water from Anthony Creek. The water is clear, slightly acid, and very soft. Its resistivity averages 96,300 ohms (at 77° F.) and its estimated total of dissolved solids is 14.5 ppm. Most of the test fishes were collected in park streams. Some of the trout were obtained from a Federal fish-cultural station and some of the carp, the goldfish, and catfish were furnished by the Tennessee Game and Fish Commission from collections made in TVA lakes.

Eighteen species of fish were killed within 6.5 hours when they were exposed to 0.5- and 1-ppm concentrations of Pro-noxfish at 56 to 66° F. Trout were the first to die and sunfish the last. Some of the carp and bullheads, and all of the goldfish survived the tests. They were kept under observation for several days in fresh water and they appeared to suffer no lasting effects from the rotenone.

Better results were obtained in tests in which the concentration of toxicant was 5 ppm for the first hour and 1 ppm for 5 hours thereafter. Fourteen species, including carp were exposed at temperatures of 63 to 65° F. and all specimens died within 5.3 hours.

The influence of low temperatures on reducing the effectiveness of rotenone was observed in several trials. In cool water (48-52° F.), some fish, including goldfish, blue catfish, and brown bullhead, survived 22.6 hour exposures to 1 ppm of Pro-noxfish. At 40°, some of the stonerollers and blue catfish, and all of the carp and goldfish survived 5.5-hour exposures to 2 ppm of the toxicant. Indeed, goldfish were exposed to the 2-ppm concentration for 77 hours at 40° but they neither turned over nor died. Four goldfish also survived a 6.5-hour exposure to 4 ppm of a Chem-fish Special, 5-percent rotenone formulation at 49°.

The only test in which any goldfish were killed was made with 8 ppm of Pro-noxfish at 67° F. The carp and blue catfish included in the test were dead within 3 hours. Five of the goldfish died after an exposure of 5.75 hours, but one fish survived.

The necessity for considering the species of fish present and the water temperature in the reclamation of a stream was clearly demonstrated by the toxicity tests. It was concluded that 23 of the 24 species of fish tested could be killed in a stream if: 1) the toxicant were applied at 5 ppm for the first hour and 1 ppm for 5 hours thereafter, and 2) the water temperatures were 60° F. or higher. The goldfish is the significant exception and the results of the tests indicate that it would be very difficult to eradicate goldfish in a stream with rotenone.

Table 2:- The results of tests with Pro-noxfish and Chem-fish special on various species of fish. The observations were made in troughs and rearing pools on Anthony Creek in May, June, and December, 1958.

Toxicant: Pro-noxfish — Concentration: 0.5 ppm

Species	Number of fish	Size range (inches)	Duration of exposure (minutes)	Reaction of fish: Turnover (minutes)	Reaction of fish: Death (minutes)	Water temperature (°F.)
Brown trout	7	6.5- 8.0	60	10- 25	40- 60	64
Rainbow trout	25	7.7-10.8	80	10- 26	28- 80	62
(wild)	6	5.1- 8.1	70	17- 26	55- 70	60-62
(wild)	4	2.6- 3.7	60	14- 30	40- 60	61-64
Eastern brook trout	10	8.2-10.7	50	10- 17	45- 50	64-66
Hogsucker	4	4.0-10.8	138	40- 55	70-138	56-66
Carp	1	9.5	320	45	320	62
	3	12.1-17.5	305	125-140	est.860 1/	64
	5	13.3-17.2	305	115-305	survived	64
	6	8.0-10.1	425	75- 85	survived	60-64
Goldfish	8	6.0-10.0	305	none	survived	64
River chub	2	4.8- 6.9	225	35- 55	135-225	60-64
Blacknose dace	23	2.0- 3.0	105	23- 44	65-105	60-63
Warpaint shiner	2	2.7- 2.9	105	28- 35	40-105	63-65
Stoneroller	2	4.5- 9.3	130	32- 40	91-130	61
Blue catfish	7	5.0-14.0	170	50- 75	135-170	64
Brown bullhead	1	10.0	260	95	260	64
	1	7.0	305	100	survived	64
Darter	1	2.4	120	34	120	60
Smallmouth bass	1	8.5	95	50	95	64
	1	13.3	335	71	est.815	64
Bluegill	2	5.6- 5.9	193	48- 52	117-193	62
Yellowbelly sunfish	6	4.7- 7.0	365	43- 60	100-365	62
Longear sunfish	1	8.0	365	60	365	62
Rock bass	4	4.6- 7.2	132	28- 70	75-132	61
Sculpin	1	5.3	111	52	111	61
Total	134					

1/ Deaths at night estimated at 1:00 AM.

Table 2:-(continued)

Toxicant: Pro-noxfish Concentration: 1 ppm

Species	Number of fish	Size range (inches)	Duration of exposure (minutes)	Reaction of fish: Turnover (minutes)	Reaction of fish: Death (minutes)	Water temperature (°F.)
Brown trout	10	6.5- 8.7	55	15- 22	40- 55	63
Rainbow trout	7	8.7-10.1	40	12- 20	27- 40	61
(wild)	16	1.7-10.8	55	15- 25	40- 55	63
Eastern brook trout	15	8.0-10.2	70	10- 23	30- 70	61-63
Hogsucker	8	4.3-11.2	175	35- 45	80- 175	61-63
Carp	1	8.4	330	90	survived	61
	5	7.5-16.1	300	80-155	205- 300	61-62
	8	12.6-15.8	1355	162-372	807-2317	48-52
Goldfish	4	7.0- 8.5	300	none	survived	62
	15	6.0-10.0	1355	none	survived	48-52
River chub	1	4.5	265	55	265	63
Blacknose dace	3	1.6- 3.0	120	25- 32	88- 120	63
Longnose dace	10	2.0- 4.0	175	20- 27	70- 175	63
Warpaint shiner	8	3.1- 5.0	160	20- 30	100- 160	63
Whitetail shiner	1	4.1	90	50	90	61
Stoneroller	36	2.8-11.6	445	25- 65	80- 445	61-63
Blue catfish	4	6.2-12.1	135	60	135	62
	7	5.6-16.1	310	70-125	200- 310	48-52
	2	12.7-14.3	1355	80- 85	1590-2315	48-52
	1	10.7	1355	120	survived	48-52
Brown bullhead	1	10.0	1355	125	survived	48-52
Darter	3	2.4- 2.6	130	40- 55	110- 130	62
Yellowbelly sunfish	2	3.2- 4.2	395	85- 88	310- 395	63
Rock bass	5	5.2- 7.1	175	30-115	60- 175	61-63
Sculpin	1	4.5	125	60	125	63
Total	174					

Table 2:-(continued)

Toxicant: Pro-noxfish — Concentration: 2 ppm

Species	Number of fish	Size range (inches)	Duration of exposure (minutes)	Reaction of fish: Turnover (minutes)	Reaction of fish: Death (minutes)	Water temperature (°F.)
Rainbow trout	2	4.2-11.3	35	15- 17	30- 35	65
	4	3.7-11.6	110	35- 45	80-110	40
Hogsucker	2	10.1-11.3	330	214-240	est.810 1/	40
Carp	3	13.0-16.8	330	none	survived	40
Goldfish	4	6.0-10.0	315	180- ..	survived	65
	4	7.5- 8.4	(77 hrs.)	none	survived	40
River chub	3	4.0- 8.3	330	90- 95	205-810	40
Stoneroller	3	4.7- 5.4	270	90- 90	250-270	40
	2	....	330	none	survived	40
Blue catfish	5	7.7-15.5	330	95-165	230-810	40
	5	8.6-16.7	900	120-180	est.900	39
Total	37					

1/ Deaths at night estimated at 1:00 AM.

Toxicant: Pro-noxfish — Concentration: 4 ppm

Carp	5	14.0-16.3	300	105-120	255-300	65
Goldfish	2	9.5-10.5	345	195-195	survived	65
	3	7.8-10.2	345	none	survived	65
Blue catfish	5	7.6-14.5	155	45- 55	130-155	65
Total	15					

Toxicant: Chem-fish special — Concentration: 4 ppm

Buffalo fish	1	15.8	390	248	est.920	49
Carp	7	6.0-16.5	390	85-205	355-920	49
Goldfish	4	6.0-10.0	390	none	survived	49
Total	12					

Table 2:-(continued)

Toxicant: Pro-noxfish — Concentration: 8 ppm

Species	Number of fish	Size range (inches)	Duration of exposure (minutes)	Reaction of fish: Turn over (minutes)	Reaction of fish: Death (minutes)	Water temperature (°F.)
Carp	3	12.2 - 13.5	175	55 - 65	155 - 175	57
Goldfish	5	7.8 - 8.0	345	90 - 130	est. 1755	57
	1	8.0	345	130	survived	57
Blue catfish	3	7.5 - 8.3	80	15 - 20	75 - 75	57
Total	12					

Toxicant: Pro-noxfish — Concentration: 5 ppm for first hour; 1 ppm thereafter

Rainbow trout	5	9.8 -10.3	95	2 - 3	20 - 35	sl.
(wild)	1	6.3 - 8.1	95	3 - 3	95 - 95	sl.
Hogsucker	8	4.5 -12.1	95	15 - 20	57 - 95	sl.
Redhorse sucker	1	7.3	157	19	157	sl.
Carp	7	6.1 -10.1	320	8 - 40	110 -320	sl.-mod.
Creek chub	1	4.4	40	10	40	sl.
River chub	1	4.4	41	10	41	sl.
Warpaint shiner	3	3.8 - 4.5	35	10 - 10	35 - 35	sl.
Whitetail shiner	1	3.2	41	11	41	sl.
Stoneroller	19	3.0 - 6.3	52	13 - 16	46 - 52	sl.
Bluegill	2	6.9 - 6.9	45	13 - 13	30 - 45	sl.
Yellowbelly sunfish	10	3.4 - 5.6	40	10 - 15	35 - 40	sl.-mod.
Longear sunfish	1	7.9	48	10	48	sl.
Rock bass	13	3.1 - 8.9	39	5 - 11	30 - 39	sl.-mod.
Sculpin	1	5.1	46	15	46	sl.
Total	77					

INDIAN CREEK

Description

Indian Creek was selected on the basis of its size and its management history as nearly ideal for the experiment in stream reclamation. It is a small and unspoiled stream. The falls (frontispiece) near the mouth is a barrier to the brown trout, suckers, carp, various cyprinids, smallmouth bass and rock bass which occur below. The fact that only rainbow trout, a few brook trout, and a small number of longnose dace inhabited the stream above the falls was considered an advantage to the experiment. Furthermore, easy access was provided by a truck road which parallels the stream for 3.5 miles and by foot-trails to the upper waters.

Indian Creek arises at 3, 900 feet elevation and flows 6.5 miles to join Deep Creek, one of the major trout streams on the eastern slopes of the park, at 1,900 feet elevation. Its discharge ranges from 8 to 44 cfs. The average width at 8 cfs of discharge is 14 feet (84 measurements) and the average depth is 5 inches (481 measurements). The water is clear, colorless, very soft, and slightly acid (pH 6.5). Its resistivity is 112,000 ohms (corrected to 77° F.) and its estimated content of total dissolved solids is 13 ppm.

There are 7.5 miles of fishable water in Indian Creek and its principal tributary, Georges Branch. Both streams are characterized by relatively straight courses, swift flow, and dense overstories of rhododendron and hardwoods. Burrows (1935) listed the pool grade in Indian Creek as B, riffle grade as B, and food grade as A. Parts of the lower watershed were mountain farms in the pre-park days but they have reverted to forest.

Eastern brook trout were native to Indian Creek and Georges Branch, but since 1920 they have been restricted to the headwaters. Rainbow trout were stocked about 40 years ago and they quickly became dominant. In sharp contrast with most streams in the park, the rainbow trout here have never afforded good fishing because of their poor growth. A survey in the fall of 1956 showed 601 rainbow trout, or 25.4 pounds per acre. Of these 580 (97 percent) or 22.1 pounds (87 percent) of fish were under the minimum legal length of 7 inches.

King (1942) reported that an effort had had been made to supplant the rainbow trout and restore brook trout in Indian Creek through stocking. Nearly 30,000 brook trout, 3 to 6 inches long, were stocked in 5 miles of the stream from 1936 to 1939 but a survey in 1940 indicated that the species persisted only in the headwaters. This failure to restore brook trout may have been due to competition from the established rainbow trout or to the unsuitability of the northern strain of brook trout used. Smith (1947) recommended that catchable-size rainbow trout be stocked in the stream whenever an increase in fishing pressure warranted stocking. The reclamation experiment afforded an opportunity, however, to remove the rainbow trout and to attempt the restoration of brook trout with a southern strain of fish.

Toxicant application

The reclamation of Indian Creek was begun during the week of April 22, 1957, when sections of the headwaters, Georges Branch and seasonal tributaries were treated with Pronoxfish at 1 ppm for 1 hour. Use was made of natural barriers during the interrupted process to preclude the escapement of fish. The lower 4.5 miles of mainstream were treated on May 1. The temperature was 59° F. and the discharge was 22 cfs - more than double the normal rate. Eighteen pounds of toxicant were dripped into the stream at the top of the section at 9:00 AM to provide a concentration of 4 ppm for 1 hour. Since the upper mile is moderately steep, with numerous falls and cascades to contribute to the rapid oxidation of the rotenone, the bolt of toxicant was strengthened at a point 0.5 mile downstream at a rate of 1 ppm for 1 hour. It was strengthened again at 1 ppm for 1 hour as it passed a checkpoint 1 mile below the initial site. Beyond this point, the stream is less rough and the bolt was not strengthened further until it reached the 3.5-mile checkpoint.

Men equipped with backpack pumps which contained undiluted toxicant accompanied the bolt downstream and sprayed all seeps and trickles that could be found. The lower one-quarter mile of Georges Branch was retreated

to prevent the escape of mainstream fish into it. Care was taken to spray all sidepools and spots where rainbow trout fry might escape the rotenone in the mainstream.

A total of 54 pounds of the toxicant was used in the reclamation. The fact that the concentration and duration of exposure were adequate in the lowermost mile of mainstream was demonstrated by the deaths of test fishes held in a livecar. The test specimens included white sucker, a hogsucker, longnose dace, blacknose dace, shiners, a stoneroller, a darter, and several sculpins. All were dead by the time that the toxicant cleared the station.

The bolt of rotenone reached the final checkpoint at Indian Creek Falls at 3:20 PM and passed by 6:15 PM. Potassium permanganate solution was applied immediately above the falls at 2.5 ppm during the 3:20-6:15 PM period to detoxify the bolt before it entered Deep Creek. The rotenone was toxic for a short distance below the falls until it was oxidized by the potassium permanganate. A few carp and suckers, 16 rainbow trout, and 5 brown trout were picked up there helpless but alive. Seven of the rainbows and 1 brown trout were held overnight in a livecar in fresh water and all recovered.

Toxication mortality

Dead trout were observed during the preliminary treatment of the headwaters and tributaries but the 3-man crew had no time to collect them. A 12-man crew participated in the treatment of the mainstream and several devoted themselves to the collection of fish. Five-hundred-ninety-two rainbow trout, weighing 58.6 pounds and ranging in length from 0.9 to 13.7 inches were collected with scap nets and check seines. Also, 85 longnose dace 2.4 to 5.5 inches long were taken. There is no doubt that many dead trout and dace escaped detection and pickup when they lodged under banks, rocks, and streamside debris. Crayfish were observed removing some. Further, it was impossible to collect the numerous dead rainbow fry which were only 0.9 to 1.1 inches long. Their size permitted them to slip through the nets and seines and they were almost indiscernible on the stream bottom.

Measurements were made on 513 of the rainbow trout and 77.5 percent were under the minimum legal length of 7 inches (table 3). Scale samples from 213 trout had from 1 to 4 annuli. Including the fry there were at least 5 age groups of trout in the stream. The majority of yearling fish were in the 4.0-4.9-inch size group and the majority of age II fish were in the 6.0-6.9-inch group. Most of the age IV fish were 10.0 to 10.9 inches long. The data indicated that some of the yearling trout would have reached legal size during their second summer and that most of the age II fish would have been 7 inches or longer during their third summer. Of the 298 trout sexed, 155 (52 percent) were males and 143 (48 percent) were females.

Restocking

Twelve-thousand Appalachian-strain brook trout were stocked in 6.5 miles of Indian Creek and 1 mile of Georges Branch in June, 1957. They ranged from 2 to 4 inches long and numbered about 60 fish per pound. Their survival and growth through the summer were good but their number was reduced sharply during the winter. In mid-December, specimens collected with an electric shocker ranged from 3.5 to 6.1 inches long.

Samples and creel checks taken in May 1958, shortly after the fishing season opened included fish that ranged from 4.7 to 8.3 inches long. All were highly colored and in excellent condition. Subsequent surveys indicated that the fish were cropped so closely under relatively heavy fishing during the 3.5-month season that few survived to spawn in the fall. The stream was stocked again with 12,000, 2- to 4-inch fingerling brook trout in June 1958. Stocking will continue until natural reproduction is adequate to sustain the population.

Reclamation results

Since September 1957, 2,033 yards (1.2 miles) of Indian Creek have been surveyed with an electric shocker. The fish collected included 562 brook trout, 35 rainbow trout and 12 longnose dace. It is significant that the only rainbow trout and longnose dace

Table 3:- The length-frequency distribution of rainbow trout from Indian Creek. A total of 592 trout was collected during the reclamation operations, of which 513 were measured and 213 were aged.

Size group (inches)	Overall distribution		Distribution by age groups							
			I		II		III		IV	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
0.1- 1.9	3	0.6	...	...	...	...	...	...	...	...
2.0- 2.9	0	...	...	...	...	...	...	...	...	...
3.0- 3.9	28	5.4	1	2.5	...	...	...	...	...	...
4.0- 4.9	172	33.5	20	50.0	1	0.8	...	...	...	...
5.0- 5.9	90	17.5	10	25.0	27	21.9	...	...	...	...
6.0- 6.9	105	20.5	9	22.5	52	42.3	...	...	...	...
7.0- 7.9	69	13.4	...	...	36	29.3	20	50.0	1	10.0
8.0- 8.9	25	4.9	...	...	6	4.9	14	35.0	...	...
9.0- 9.9	9	1.8	...	...	1	0.8	4	10.0	1	10.0
10.0-10.9	10	2.0	...	...	...	...	2	5.0	7	70.0
11.0-11.9	0	...	...	...	...	...	...	...	...	...
12.0-12.9	1	0.2	...	...	...	...	...	...	1	10.0
13.0-13.9	1	0.2	...	...	...	...	...	...	...	...
Totals	513	100.0	40	100.0	123	100.0	40	100.0	10	100.0

which survived the reclamation were fry. It is possible that some of the survivors were late-hatching ova at the time of the reclamation. On the basis of the distance surveyed and excluding natural mortality, it is estimated that at least 227 rainbows and 78 longnose dace survived in the 7.5 miles of reclaimed water. Although many of the trout might be removed as immature fish during surveys and by anglers, some reproduction may occur eventually.

Several disadvantages were anticipated when the spring-time reclamation of Indian Creek was scheduled and all of them were strikingly demonstrated. First, the date for the reclamation had to be set between the expected emergence of rainbow trout fry in late April and the opening of the fishing season in mid-May. Consequently, there was little opportunity to adjust the schedule in the event of unfavorable weather or high water. Second, a late spring would result in cold water. Low temperatures would delay the hatch of trout ova and also reduce the effectiveness of the toxicant. And third, a wet spring would cause high water levels and abundant seeps and trickles. Thus, the treatment of the stream with rotenone would be complicated. The spring was, in fact, both late and wet.

ABRAMS CREEK

Description

Abrams Creek is one of the longer and larger streams in the park. It is relatively fertile since it flows through limestone deposits in Cades Cove but intensive agriculture in the Cove contributes to some warming and silting of the tributaries and main-stream. A scenic falls, 25 feet high, is located several miles downstream from the Cove and 14.6 miles upstream from the mouth into the Little Tennessee River. The stream above the falls is referred to as the upper section and that below the falls is known as the lower section. The terrain is rough and an approach to the falls and most of the lower section of the stream can be made only by foot-trails. Access by vehicle to the lower section is limited to one point in the vicinity of the public campground which is approximately midway between the falls and the mouth.

The stream below Abrams Falls is characterized by short cascades and very long, deep pools. Most of it cannot be waded and this, in addition to the dense, streamside cover, hinders both fishing and survey work. At the campground, the stream averages 63 feet in width at the normal discharge rate of 90 cfs. The gradient is approximately 44 feet per mile. The water is clear, slightly brown, and soft. Its resistivity is 13,700 ohms (at 77° F.) and its estimated content of total dissolved solids in 60 ppm.

The principal game fishes in lower Abrams Creek below the falls were rainbow trout and smallmouth bass. The falls marked the upstream limit for carp, redhorse suckers, freshwater drum, catfishes, sauger, sunfishes, warmouth, rock bass, as well as smallmouth bass. Rainbow trout were stocked about 60 years ago and became dominant in the upper section and in tributaries to the lower section. They occurred much less abundantly in the main-stream below the falls, presumably due to heavy competition from other species.

King (1942) noted that rainbow trout in Abrams grew faster than in other streams of the park. He added that the trout fishery, especially in the upper section, improved rapidly after the park acquired the land in 1937. Prior to this time, the stream had been badly abused by seining, dynamiting, and bait fishing. Little could be done to improve the fishery in the lower section other than to stock catchable-size trout and to provide protection from poaching. The success of these measures was limited, however, by the preponderance of centrarchids and non-game fishes.

The opportunity to reclaim the lower section of Abrams Creek arose in connection with the creation of Chilhowee Lake on the Little Tennessee River. The Aluminum Corporation of America had a power dam 64 feet high nearly completed on the river at Chilhowee, Tennessee. The 1,690-acre lake to be impounded by the dam would border the southwest corner of Great Smoky Mountains National Park and inundate 2.6 miles of lower Abrams Creek.

The Tennessee Game and Fish Commission recognized an opportunity to promote a rainbow trout fishery in the new lake. Several months prior to the inundation, state biologists laid the ground work for the reclamation of the Little Tennessee River between the new dam and Calderwood Dam, 10 miles upstream. Since Abrams Creek is a major tributary to the river within the area, the biologists requested that the National Park Service and Fish and Wildlife Service reclaim the 14.6-mile section of stream below Abrams Falls. It was considered essential that the abundant carp and rough fish in both the river and Abrams Creek be reduced or eliminated so that stocked rainbow trout could become established in the new lake.

Representatives of the Tennessee Game and Fish Commission, the Tennessee Valley Authority, the National Park Service, and U.S. Fish and Wildlife Service met at Great Smoky Mountains National Park on May 3, 1957. All were in accord on the merits of establishing rainbow trout in the new lake. An agreement was made that the reclamation of the Little Tennessee River and Abrams Creek would be conducted simultaneously by the respective State and Federal crews. The State representative anticipated that the reclamation would take place in July 1957, during the brief interval when Calderwood powerhouse would be shut down. The river below the powerhouse would be largely emptied at this time to permit installation of the last gate-sill in Chilhowee Dam. The low water would facilitate the State's reclamation job, and the completion of the gate-sill would prevent reoccupation of the reclaimed section by rough fish from below the new dam.

A review of park files showed that there was very little survey data available on Abrams Creek. A program was initiated immediately to gather necessary information on the stream, its tributaries and its fishes. In addition, National Park Service crews undertook to clear or build foot and jeep trails to facilitate access to the stream. The program was barely underway when notice was received on May 21 that Chilhowee Dam would be completed on June 9 and that reclamation operations would have to be conducted on that date. In consequence, only the most essential observations on Abrams could be made before the reclamation.

Toxicant application

The National Park Service set up a base camp on Abrams Creek several days prior to the reclamation operation. From this point, equipment and supplies of rotenone were packed in and cached at Abrams Falls at strengthening stations, and on remote tributaries. Park personnel provided the rather elaborate precautions which were necessary to protect the caches from marauding black bears.

State biologists specified that the bolt of rotenone in Abrams Creek had to reach the mouth into the Little Tennessee River precisely at noon on Sunday, June 9, in order to meet their bolt. The observations with salt and the resistivity meter had shown that the toxicant would require 20 or more hours depending on water levels to move from Abrams Falls 14.6 miles downstream to the mouth. The volume of flow in Abrams on the morning of June 8 was 92 cfs. At this rate, rotenone introduced at the falls at noon on the 8th would reach the mouth at noon on the 9th.

The treatment of Abrams was initiated at the falls at 12:20 PM on Saturday and continued to 6:20 PM. Pro-noxfish was applied by means of a metered drip system at the rate of 5 ppm for the first hour and 1 ppm for 5 hours thereafter. Other crews made carefully scheduled 6-hour, 1-ppm applications of rotenone in Rabbit Creek, Whiteoak Flat Branch, and Kryder Branch, all of which enter Abrams within 2 miles below the falls. Also, the doses in Mill Branch, Buckshank Branch, Cooper Branch, Bell Branch and Panther Creek were timed to meet the bolt of toxicant in Abrams. Strengthening doses were added in the mainstream at appropriate sites and times during the night and in the early morning. In the night the bolt of rotenone was preceded downstream by a bolt of salt so that the progress of the toxicant and its arrival at strengthening stations could be checked accurately with a resistivity meter.

The bolt of toxicant reached Abrams Campground at 10:00 PM Saturday; Bell Branch at 4:00 AM Sunday; and the mouth of Abrams precisely at 12:00 noon Sunday. The entire operation was accomplished very smoothly by the crews which worked in relays down the stream during the 23.6-hour period.

A total of 888 pounds of Pro-noxfish, worth $555, was used. Twenty-five men of the Fish and Wildlife Service and National Park Service participated in the pre-reclamation and reclamation activities. Their 75 man-days of work represented approximately $1,100 in salaries. Camp equipment was furnished by the park and the mess bill for 4 days amounted to $177. Other expenses including salt blocks, truck, jeep, and trail-dozer costs, and incidentals were estimated at $200. The total cost of the survey, trail-clearing, camp maintenance, and reclamation job on Abrams was $2,032.

Toxication mortality

Toxic concentrations of rotenone were maintained for more than 6 hours in a long bolt moving downstream. Water temperatures were favorable and ranged from 66° at the falls to 71° F. at the mouth. Test fishes including hogsuckers, carp, shiners, and rock bass in livecars at Abrams Campground were killed before the toxicant cleared the station. None but dead carp, suckers, lamprey, and other species were observed in the stream on June 9 and 10.

Forty-six species of fish were picked up in Abrams and tributaries during the reclamation (table 4). They included 16 species which had not been recorded previously in the park. The public was permitted to gather dead fish and several checking stations were manned to list the species, numbers, and sizes taken. Additional specimens which were representative of species in the stream were collected by biologists. The number of fish checked was 3,233 and the total weight was 977 pounds. Of these 2,237 were food and game fish and their total weight was 808 pounds.

The numbers recorded for the various species in no way represent their relative abundance since the pick up was very selective in respect to species and to size of the fish. Some persons sought only large trout, others collected only trout and smallmouth bass, and most of them ignored all fish which they considered too small to be included in the possession limit. The timing of the reclamation discouraged greater public participation in gathering fish. The rotenone passed through the only accessible sections of the stream during the night. Since the night was stormy and wading was dangerous, many would-be collectors visited the scene but passed up the opportunity to pick up fish.

Most of the 448 rainbow trout checked were taken between the falls and Abrams Campground. They ranged from 1.7 to 14.8 inches long and the degree of selectivity exercised by collectors was illustrated by the fact that 84 percent of the fish were over 7 inches long (table 5). Young-of-the-year trout ranged from 1.7 to 3.2 inches long and including them, there were 6 year classes represented in the collections.

An examination of scales from 209 trout showed that the majority of age I fish were 7.0 to 7.9 inches long. The majorities of age II and age III trout were 9.0 to 9.9 and 10.0 to 11.9 inches long respectively. A comparison of the Indian Creek and Abrams Creek rainbow trout per age group indicated that fish in the latter stream averaged approximately 2 inches longer. Only a fraction of this difference can be attributed to growth achieved in the 5 weeks between reclamation jobs. Most of it is due to the better conditions for growth in Abrams Creek.

The second most important game fish in lower Abrams was the smallmouth bass. The 475 specimens picked up between the falls and the mouth ranged from 1.2 to 18.5 inches in length and from 0 to 8 years in age (table 6). Their rate of growth was relatively slow, as indicated by an examination of scales from 76 specimens. Twenty-four, age IV fish ranged from 6.5 to 10.6 inches and averaged 9.2 inches long. Twenty-two, age V fish ranged from 7.8 to 15.3 inches and averaged 10.6 inches long.

Rock bass were abundant from the falls downstream. They were perhaps the principal competitor of the rainbow trout and smallmouth bass. These species however, is not considered a valuable game fish in the vicinity of the park. Of the 725 specimens gathered during the reclamation, 676 were measured (table 7). They ranged from 2.1 to 11.5 inches and averaged 6.4 inches long. Twenty 5.9 to 9.7 inch fish ranged from 3 to 8 years in age.

Table 4 :- Fishes collected during the reclamation of lower Abrams Creek and tributaries in June 1957. Those species denoted by an asterisk are new records for Great Smoky Mountains National Park.

	Common name	Scientific name
1.	*Chestnut lamprey	Ichthyomyzon castaneus
2.	American brook lamprey	Lampetra lamottei
3.	*Gizzard shad	Dorosoma cepedianum
4.	Rainbow trout	Salmo gairdneri
5.	Eastern brook trout	Salvelinus fontinalis
6.	Hogsucker	Hypentelium nigricans
7.	White sucker	Catostomus c. commersoni
8.	Black redhorse sucker	Moxostoma duquesnei alleghaniensis
9.	Golden redhorse sucker	Moxostoma erythrurum
10.	*Carp	Cyprinus carpio
11.	Stoneroller	Campostoma anomalum
12.	River chub	Hybopsis micropogon
13.	Bigeye chub	Hybopsis amblops
14.	Popeye shiner	Notropis ariommus telescopus
15.	*Southern emerald shiner	Notropis atherinoides dilectus
16.	Warpaint shiner	Notropis coccogenis
17.	Central common shiner	Notropis cornutus chrysocephalus
18.	Whitetailed shiner	Notropis galacturus
19.	Tennessee shiner	Notropis leuciodus
20.	Spotfin shiner	Notropis spilopterus
21.	*Blacktail shiner	Notropis stigmaturus
22.	Suckermouth minnow	Phenacobius catostomus
23.	Blacknose dace	Rhinichthys atratulus obtusus
24.	Creek chub	Semotilus a. atromaculatus
25.	*Channel catfish	Ictalurus punctatus
26.	*Blue catfish	Ictalurus furcatus
27.	*Yellow bullhead	Ameiurus natalis
28.	*Black bullhead	Ameiurus melas
29.	*Stonecat	Noturus flavus
30.	*Brindled madtom	Schilbeodes miurus
31.	Studfish	Fundulus catenatus
32.	Sauger	Stizostedion canadense
33.	*Logperch	Percina c. caprodes
34.	Greenside darter	Etheostoma blennioides
35.	Bluebreast darter	Etheostoma camurum
36.	Fantail darter	Etheostoma flabellare
37.	Redlined darter	Etheostoma rufilineatum
38.	Smallmouth bass	Micropterus d. dolomieui
39.	*Warmouth	Chaenobryttus coronarius
40.	Rock bass	Ambloplites r. rupestris
41.	*Yellowbelly sunfish	Lepomis auritis
42.	*Orangespotted sunfish	Lepomis humilis
43.	Longear sunfish	Lepomis m. megalotis
44.	Bluegill	Lepomis m. macrochirus
45.	*Freshwater drum	Aplodinotus grunniens
46.	Freshwater sculpin	Cottus carolinae

Table 5 :- The length-frequency distribution of rainbow trout from Abrams Creek. A total 448 trout was collected during the reclamation operations, of which 443 were measured and 209 were aged.

Size group (inches)	Overall distribution		Distribution by age groups									
			I		II		III		IV		V	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1.0- 1.9	3	0.7	...	...	...	...	...	...	...	...	...	...
2.0- 2.9	15	3.4	...	...	...	...	...	...	...	...	...	...
3.0- 3.9	2	0.5	...	...	...	...	...	...	...	...	...	...
4.0- 4.9	...	...	...	...	...	...	...	...	...	...	...	...
5.0- 5.9	9	2.0	1	3.3	1	0.8	...	...	...	...	...	...
6.0- 6.9	40	9.0	10	33.4	1	0.8	...	...	...	...	...	...
7.0- 7.9	64	14.5	14	46.7	9	7.8	...	...	...	...	...	...
8.0- 8.9	77	17.4	4	13.3	30	25.9	4	10.0	...	...	...	...
9.0- 9.9	112	25.3	1	3.3	51	44.0	7	17.5	...	...	...	...
10.0-10.9	55	12.4	...	...	18	15.5	12	25.9	1	4.8	...	...
11.0-11.9	40	9.0	...	...	4	3.5	13	32.5	5	23.8	...	...
12.0-12.9	13	2.9	...	...	2	1.7	4	10.0	7	33.3	...	...
13.0-13.9	8	1.8	...	...	...	...	...	...	3	14.3	2	100.0
14.0-14.9	5	1.1	...	...	...	...	...	...	5	23.8	...	...
Totals	443	100.0	30	100.0	116	100.0	40	100.0	21	100.0	2	100.0

Table 6:- The length-frequency distribution of smallmouth bass from Abrams Creek. A total 475 bass was collected during the reclamation operations, of which 470 were measured and 76 were aged.

Size group (inches)	Overall distribution		Distribution by age groups									
			III		IV		V		VI		VII		VIII	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1.0- 1.9	1	0.2	...	...	...	...	...	...	...	...	...	...	...	...
2.0- 2.9	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3.0- 3.9	11	2.3	...	...	...	...	...	...	...	...	...	...	...	...
4.0- 4.9	7	1.5	...	...	...	...	...	...	...	...	...	...	...	...
5.0- 5.9	12	2.6	...	...	...	...	...	...	...	...	...	...	...	...
6.0- 6.9	50	10.6	4	50.0	1	4.1	...	...	...	...	...	...	...	...
7.0- 7.9	88	18.7	3	37.5	2	8.3	1	4.6	...	...	...	...	...	...
8.0- 8.9	85	18.1	1	12.5	4	16.7	1	4.6	...	...	...	...	...	...
9.0- 9.9	83	17.7	...	...	13	54.2	8	36.4	1	6.8	...	...	...	...
10.0-10.9	56	11.9	...	...	4	16.7	4	18.1	2	13.3	...	...	...	...
11.0-11.9	30	6.4	...	...	...	...	4	18.1	3	20.0	...	...	...	...
12.0-12.9	16	3.4	...	...	...	...	2	9.0	3	20.0	...	...	...	...
13.0-13.9	12	2.6	...	...	...	...	1	4.6	2	13.3	1	20.0	...	...
14.0-14.9	7	1.5	...	...	...	...	...	...	2	13.3	...	...	...	...
15.0-15.9	8	1.7	...	...	...	...	1	4.6	2	13.3	4	80.0	...	...
16.0-16.9	2	0.4	...	...	...	...	...	...	...	...	...	...	2	100.0
17.0-17.9	1	0.2	...	...	...	...	...	...	...	...	...	...	...	...
18.0-18.9	1	0.2	...	...	...	...	...	...	...	...	...	...	...	...
Totals	470	100.0	8	100.0	24	100.0	22	100.0	15	100.0	5	100.0	2	100.0

Table 7:- The length-frequency distribution of selected species among the 3,233 fish checked on Abrams Creek.

Length group (inches)	Golden redhorse sucker		Hogsucker		Carp		Blue and channel catfish		Rock bass	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
1.0- 1.9	...	....	...	....	...	....	...	....	...	....
2.0- 2.9	1	0.6	1	0.5	...	....	...	....	4	0.6
3.0- 3.9	1	0.6	2	1.0	...	....	...	....	9	1.3
4.0- 4.9	7	4.3	4	2.1	...	....	...	....	66	9.8
5.0- 5.9	5	3.1	1	0.5	...	....	...	....	172	25.4
6.0- 6.9	...	....	2	1.0	...	....	...	....	202	29.9
7.0- 7.9	4	2.4	7	3.7	...	....	...	....	117	17.3
8.0- 8.9	4	2.4	18	9.5	...	....	...	....	61	9.0
9.0- 9.9	13	7.9	17	9.0	...	....	1	1.3	34	5.0
10.0-10.9	6	3.6	40	21.2	...	....	...	....	10	1.5
11.0-11.9	25	15.1	45	23.9	...	....	2	2.7	1	0.2
12.0-12.9	24	14.5	31	16.4	...	....	6	8.0	...	....
13.0-13.9	22	13.3	16	8.5	...	....	8	10.7	...	....
14.0-14.9	15	9.1	4	2.1	2	5.3	18	24.0	...	....
15.0-15.9	16	9.6	...	....	2	5.3	12	16.0	...	....
16.0-16.9	8	4.9	...	....	2	5.3	10	13.3	...	....
17.0-17.9	9	5.5	...	....	11	28.9	5	6.7	...	....
18.0-18.9	3	1.9	...	....	9	23.6	6	8.0	...	....
19.0-19.9	...	....	...	....	4	10.5	5	6.7	...	....
20.0-20.9	1	0.6	...	....	5	13.2	1	1.3	...	....
21.0-21.9	...	....	...	....	1	2.6	...	....	...	....
22.0-22.9	...	....	...	....	...	....	1	1.3	...	....
23.0-23.9	1	0.6	...	....	2	5.3	...	....	...	....
24.0-24.9	...	....	1	0.6	...	....	...	....	...	....
Totals	166	100.0	188	100.0	38	100.0	75	100.0	676	100.0

The golden redhorse was the more important of the 4 species of suckers found in Abrams in respect to size, number, and choice as a food fish (table 7). Of the 181 specimens checked, 166 ranged from 2.3 to 24.3 inches long. They occurred commonly in all sizes below the falls. There were 198 hogsuckers, 2.6 to 14.8 inches long recorded. This fish is native to many of the park streams but it appeared to occur more abundantly in Abrams than elsewhere. It was a matter of some surprise that it was considered a food fish by the public.

Carp were observed throughout the treated area. Contrary to expectations they were not favored by the public and relatively few were checked in. Many persons reported that they had captured large carp and had thrown them into the woods. The 38 specimens which were measured ranged from 14.4 to 23.5 inches long. No small ones were observed despite a careful search by biologists. The assertion made by Tennessee biologists that carp would not spawn in Abrams appears valid.

Seventy-five channel and blue catfish were collected in the lower 4 or 5 miles of Abrams. They ranged from 9.5 to 22.0 inches long and weighed a total of 89 pounds. Since no small specimens were found, it is assumed that neither species reproduces in Abrams. They apparently migrated into the stream from the Little Tennessee River, but their small numbers made them relatively unimportant as game fish.

Stonerollers were common in lower Abrams as they are in most of the park streams. They are esteemed as a food fish by local people and many were collected. Only 153 specimens were measured and they ranged from 2.3 to 8.0 inches long.

Among the sunfishes collected, warmouth, bluegill, and orangespotted were rare. Thirty-nine longear sunfish averaged 5.2 inches (range: 2.9-8.1) and 58 yellowbelly sunfish averaged 6.1 inches long (range: 2.7-8.1).

Only 2 saugers, 11.4 and 13.4 inches long, were observed. Twenty-one freshwater drum were collected and they ranged from 5.6 to 17.2 inches. Three gizzard shad, 8 to 9 inches long, were taken within one-half mile of the mouth of the stream.

Larvae of the American brook lamprey and chestnut lamprey were abundant in riffle areas near the mouth of Abrams, but only dead specimens could be found on the day after the application of the toxicant. The 24 larvae measured ranged from 0.7 to 8.0 inches long. One adult chestnut lamprey, 9.6 inches long was taken.

Chubs, minnows and studfish were abundant. Among them creek chubs ranged from 1.8 to 11.0 inches, warpaint shiners from 1.8 to 8.4 inches and studfish from 3.7 to 4.5 inches long.

Restocking

The lower section of Abrams Creek was restocked with rainbow trout. Within the mouth following the treatment of the stream with rotenone, 2,400 legal-size fish were released in the vicinity of the campground. Many of them were creeled before the fishing season closed on August 31. In October and November, a total of 31,000, 3 to 7-inch rainbow trout of the Eagle Nest (New Mexico) strain was distributed to several points on the stream by truck and by backpack. Within a short time, the fingerlings had spread out widely from the stocking points and they appeared to be doing well.

Large numbers of 7 to 9-inch rainbow trout were observed spawning in the mainstream and tributaries during the week of March 5-12, 1958. The redds were sampled for ova since it was believed that the trout were too young to spawn successfully. Numerous eggs were found and selected redds were kept under observation. Fry began to emerge on April 20, and within 2 weeks they were abundant in the stream. On the basis of the very successful hatch, plans to stock 50,000 fingerlings in June were cancelled.

Reclamation results

Excellent fishing for rainbow trout was afforded in the reclaimed section of Abrams Creek during the 1958 season. A partial creel census was made during opening week, May 16-22, and the 137 anglers contacted had 689 trout. The average catch per fisherman was 5 trout (the

daily possession limit) and the rate of catch exceeded 1 fish per hour of effort. The trout averaged 10.6 inches long and ranged from 8.0 to 13.8 inches. They were beautifully-conditioned, hard-fighting fish.

The quality of fishing in the reclaimed waters compared more than favorably with that on upper Abrams. The upper section between Cades Cove and the falls is considered to be one of the best pieces of trout water in the southeast. Yet, the average catch of the 57 fishermen checked here during opening week was 4 trout which averaged 9.5 inches long and ranged from 7 to 18 inches.

A complete creel census on the reclaimed section of Abrams would have been desirable but the partial coverage from May 16 to 22 indicated that an organized census for the season would be impractical. The campground was not so much a focal point for anglers as we thought it would be. The great majority of fishermen were local and they approached remote sections of the stream via trails across the mountains. It was apparent that relatively few of them could be checked unless several creel clerks patrolled the 14.6 miles of stream on foot each day. We relied, therefore, on the statements of park personnel that the quality of fishing held up throughout the season.

Much of the reclaimed section of Abrams Creek is deep and unwadeable and surveys of fish are difficult to make. AC and DC electrofishing rigs have been employed on selected sections of the mainstream - with and without the aid of a boat. AC gear and cresol have been used on some of the small and remote tributaries.

Checks of fishermen and surveys made on Abrams during the summer following the reclamation failed to show the presence of any fish other than stocked rainbow trout. Only rainbows were observed during additional surveys in October and November. During the fall, however, there were reliable reports that rough fish were present in considerable numbers in Chilhowee Lake. Observers considered it possible that many coarse fishes were sluiced out of Calderwood Lake and down into Chilhowee at the time that the new lake was filled. It would be, therefore, only a matter of time before the rough fish would migrate into Abrams Creek.

Surveys were resumed in March after the severe winter weather abated. Rainbow trout from 3.0 to 8.8 inches long were abundant in Kingfisher Branch but no other species were found. On the other hand, 5 blacknose dace were collected in addition to rainbow trout in the upper waters of Rabbit Creek. The occurrence of blacknose dace was not unexpected since this species is often and singly associated with trout above barrier falls in park streams. No attempt was made during the reclamation to eradicate the dace above the falls on Rabbit Creek. Only rainbow trout were observed in the mainstream in March.

Electrofishing in the vicinity of Abrams Campground in early April showed the presence of many trout. One rock bass was also taken. Park personnel reported at this time that rough fish were beginning to be observed in the lowermost section of Abrams near Chilhowee Lake. These fish made rapid progress upstream through the summer. In September, 11 species in addition to rainbow trout were collected by electrofishing in 360 yards of stream near the campground. Included were hogsuckers, stonerollers, warpaint shiners, blacknose dace, logperch, 2 species of darters, bluegill, longear sunfish, yellowbelly sunfish, and rock bass. A 100-yard station on Rabbit Creek yielded small numbers of stonerollers, warpaint shiners, and darters which had moved in since the same area was surveyed in March. Many of the rough fish were adults which could not have escaped detection in previous surveys. There is no doubt that they migrated into Abrams and tributaries from the new lake.

The trout collected in the mainstream in September ranged from 2.9 to 11.6 inches long. The young-of-the-year which hatched in April had made excellent growth and ranged from 2.9 to 6.8 inches long. Over 60 percent of this age group were 4 or more inches long whereas the majority of fish of this age in other streams of the park were under 4 inches. The trout collected in Rabbit Creek ranged from 3.1 to 9.4 inches and again the 0-age fish showed better than average growth for park streams. The abundance of young-of-the-year fish in Abrams and tributaries was such that no stocking with fingerlings or legals was scheduled for 1959.

CONCLUSIONS

1. The reclamation of streams with rotenone is feasible and practical. Forty-six species of game and rough fishes were removed from Indian and Abrams Creeks in 1957.

2. The salt-resistivity technique was employed successfully to estimate the stretch-out, dilution, and velocity of a toxicant moving downstream.

3. A sufficient duration of exposure to rotenone is as necessary as an adequate concentration of the toxicant to kill fish in running water. In Indian Creek a concentration of 1 ppm of toxicant maintained for 1 hour was sufficient at 59° F. to kill trout and dace. In Abrams Creek the presence of carp necessitated that a concentration of 1 ppm be maintained in an uninterrupted bolt for 6 hours at 66° to 71°.

4. Streamside toxicity tests demonstrated that goldfish in streams would be very difficult to kill with rotenone.

5. Reclamation projects on streams should be scheduled before or well after the spawning and hatching periods of undesirable fishes. Also, every advantage should be taken of low water levels and high water temperatures to increase the effectiveness of the operations and to reduce the costs of the toxicant and manpower. Streams in the Smokies, for example, should be reclaimed in the late summer or early fall.

6. It is important to select streams for reclamation which have natural or man-made barriers to fish migration to prevent reinfestation by undersirable species. The considerable investment necessary to reclaim and restock a stream may provide only very temporary benefits unless such barriers exist.

7. The stocking of fingerling-size brook trout and rainbow trout of selected strains in Indian and Abrams Creeks respectively, was successful. Survival and growth were good and most of the fish were of legal size (7 inches) during the 1958 fishing season. The brook trout were cropped so heavily that few survived to spawn in the fall. The rainbow trout on the other hand spawned abundantly in the spring before the fishing season. The hatch and survival of this species in Abrams Creek has been so good that further stocking has been postponed.

SUMMARY

A 7.5-mile section of the Indian Creek watershed in Great Smoky Mountains National Park was treated with rotenone in April and May 1957. Extensive, preliminary observations were made on the stretch-out, dilution, and velocity of a toxicant in running water by means of the salt-resistivity technique. Streamside toxicity trials with rotenone indicated that a 1 ppm concentration of Pro-noxfish maintained for 1 hour would be sufficient to kill rainbow trout, brook trout, and longnose dace at water temperatures close to 60° F. All fish in the stream with the exception of some trout fry and dace fry were killed.

Indian Creek was restocked with fingerling-size, Appalachian-strain brook trout in June 1957 with good results. Most of the fish that survived the winter reached legal size in 1958 and were heavily cropped by anglers. There is good reason to believe that the native-strain brook trout will become established in Indian Creek and afford better fishing than rainbow trout did. A barrier falls near the mouth of the stream prevents the migration of rough fishes into the reclaimed waters.

A 14.6-mile section of Abrams Creek and its tributaries below Abrams Falls were treated with Pro-noxfish in June 1957. Toxicity trials in streamside troughs indicated that a 1-ppm concentration of toxicant would have to be maintained in a continuous bolt for 6 hours at temperatures of 66° to 71° F. to kill carp and other resistant species. Forty-six species were killed and no survivors were found during the summer and fall.

Abrams was stocked with 2,400 legal-size rainbow trout in June and July to furnish fishing for guests at Abrams Campground. Over 30,000 fingerling-size rainbow trout were stocked in the fall. They survived well and grew rapidly. Many of them spawned during the following March and an abundant hatch occurred in April. Further stocking has been unnecessary. Fishing was excellent during the 1958 season.

There is no barrier at the mouth of Abrams Creek to prevent the ingress of fish from Chilhowee Lake. Accordingly, surveys in September 1958 showed that 11 species of fish had moved into Abrams from the lake.

The results on Indian and Abrams Creeks have shown that sport fisheries for selected species can be greatly improved through the elimination of undesirable fishes with rotenone. The survival, growth, and reproduction of trout are greater in the reclaimed streams than in comparable untreated waters. It is recommended, however, that reclamation operations be restricted to streams which have natural or man-made barriers to prevent reinfestation by undersirable fish.

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